Preliminary approach for crypt detection in Inflammatory Bowel Disease

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Bassem Ben Cheikh[1,2,3,*], Philippe Bertheau[4], Daniel Racoceanu[1,2,3]

[1] Sorbonne Universités, UPMC Univ Paris 06, UMR 7371, U1146, Lab. d'Imagerie Biomédicale, F-75013, Paris, France.
[2] CNRS, UMR 7371, Laboratoire d'Imagerie Biomédicale, F-75013, Paris, France.
[3] INSERM, U1146, Laboratoire d'Imagerie Biomédicale, F-75013, Paris, France.
[4] Saint-Louis Hospital, Department of Pathology, APHP, and University Paris Diderot USPC, Paris, France
[*] bassem.bencheikh@lib.upmc.fr.

Abstract *- **Crypt architecture is one of the most significant histological features used for the examination of colorectal biopsy specimens enabling clinical decisions in the investigation of Inflammatory Bowel Diseases. However, the architecture modelling remains a challenging problem leading to variability in reporting and subjectivity in pathological examination. In this context, intestinal gland detection represent a necessary step before a clinical study of their architecture. This work presents a graph-based technique describing spatial relationships over sparse structures for crypt detection using morphological mesh filtering operators.***

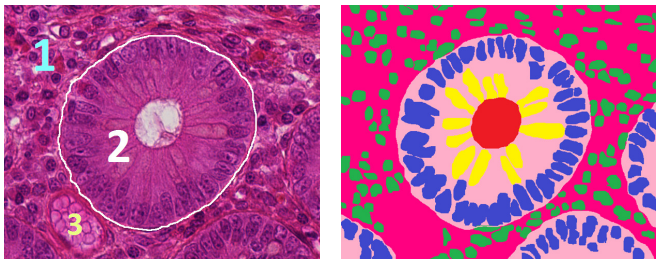
Index Terms *- **Image Processing, Medical Informatics, Microscopy.***

I. INTRODUCTION

Inflammatory Bowel Diseases (IBDs) are characterized by chronic inflammation of the gastrointestinal tract, principally the colon and small intestine. The routine diagnosis of an IBD is based on biopsy; where a tissue is removed from the suspected organ and examined by the pathologist under a microscope. A biopsy of an affected colon tissue may show abnormalities in its histological structure. The morphological features of the intestinal glands are significant indicators for the severity of the disease. In order to introduce these morphological features, gland detection is a necessary step ahead. For this purpose, most of the existing methods use replicated classifications of color [1], texture [2], or graph [3] features. In this work, we present a new graph-based technique and morphological mesh filtering transformations for intestinal gland detection. Section 2 presents an overview of our method and section 3 presents the results and the limitations of this approach.

II. MATERIALS AND METHODS

One of the most distinctive properties of a gland is that they usually exhibit a closed shape structure surrounded by a layer of epithelial cell nuclei. Compared to the connective tissue, the inner area of an intestinal gland doesn't contain nuclei, being composed of cytoplasm, goblet cells, and lumen (fig 1). Based on these observations, we propose a novel graph approach to distinguish the structure of an intestinal gland from the rest of the tissue. For this purpose, a biopsy tissue image is first decomposed into sets of points, associated to different tissue components. Furthermore, we use their distribution characteristics in order to determine the locations of gland structures.



(a) (b)

Figure 1: (a.1) connective tissue, (a.2) crypt and (a.3) blood vessel. (b) Red: lumen. Yellow: goblet cells. Blue: epithelial cell nuclei. Green: immune system cell nuclei. Pink: cytoplasm. Purple: stroma.

II.1. Image decomposition

One of the most widely used routine-stains in histopathology is the Hematoxylin and Eosin (H&E). In a typical image of a H&E-stained colorectal tissue, there are mainly three colour groups of pixels. The nucleus pixels have dark purple colour, whereas the cytoplasm and stroma pixels have varying degrees of pink, and lumen pixels are white. Hence, the pixels of an image are quantized into three clusters with the k-means algorithm.

II.2. Node identification

In order to set up nodes to lead the graph reconstruction, we need first to translate the color class information to node information. For this purpose, a grid is placed on the resulting segmented image. For each grid entry we calculate the ratio of pixels belonging to a color class to the size of the grid entry. If this ratio is higher than a threshold then a node is set within the grid entry.

II.3. Graph generation

After identifying the set S_1 of nodes representing stroma and crypt cytoplasm, as the set S_2 of nodes representing nuclei (fig 2.a), we reconstruct the Gabriel graph (G_g) of the set S_1. Thereafter, an edge of $G_g(S_1)$ is conserved if the smallest circle containing the edge doesn't contain any point of S_2. This new property minimize vertex connections in areas where nodes of S_1 and S_2 coexist, compared to areas where there are only nodes of S_1 (see fig. 2.b).

II.4. Morphological mesh filtering

The reconstructed graph identifies mainly the inner areas of the crypts and some small objects in the connective tissue considered as noise. Morphological operators acting like geometrical filters on graphs were introduced in [4]. Unlike classical mathematical morphology, the structuring elements are considered as the neighborhoods in the graph. We define the neighborhood of an edge $E \in G_g$ as the set of all edges of G_g sharing one vertex with E. By keeping all the properties and definitions introduced in [4], we apply the *opening* operator to the obtained graph, noted $G_{1|2}$.

II.5. Crypt boundary detection

In this step, the obtained graph, noted $o(G_{1|2})$, is dilated considering the spatial distribution of epithelial cell nuclei that surround the crypt. Therefore, the Delaunay graph (D_g) of the set S_2 is reconstructed. Thereafter, holes are created in $D_g(S_2)$ in areas where it intersects with $o(G_{1|2})$ and then eroded twice to make the holes large enough to fit the shape of the crypt (fig 2.c). Next, the graph $G_{1|2}$ is dilated until intersection with the remodeled D_g. Finally, to visualize the boundary of the crypt, we use the linear curve α-shape (e.g. α-shape is the space generated by point-pairs that can be touched by any empty disc of radius α)

III. RESULTS

To assess the effectiveness of our approach we use a dataset composed of 28 Whole Slide Images (WSI) of H&E-stained colon tissues. 64 regions of interest (ROI) were drawn by the pathologist. This dataset contains 1824 crypts in total. Each ROI's image is processed at 20X magnification.

IV. DISCUSSION-CONCLUSION

In this work, we propose a dual graph-based mathematical morphology to analyze spatial relationships over sparse structures. Gabriel and Delaunay graph properties are used to study the spatial dependencies between distinct point-sets, associated to different image components. Beside, we use morphological mesh filtering to refine their geometric shapes. The theoretical approach finds its purpose in the detection of glandular structures in human colon tissues, which could be a first step toward the study of Inflammatory Bowel Disease.

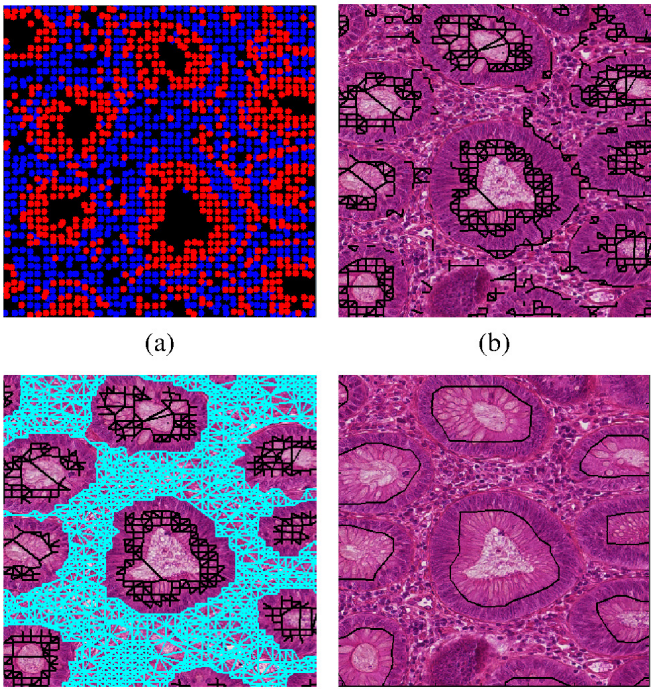


Figure 2: (a) Red: S_1, blue: S_2. (b) Graph $G_{1|2}$. (c) Black: $opening(G_{1|2})$, cyan: $eroded(D_g(S_2))$. (d) α-shapes.

Precision	*Sensitivity*	*F-measure*
0.72	0.84	0.78

Table 1: Quantitative evaluation of our approach.

ACKNOWLEDGMENTS

This study has been possible due to the support of the project FlexMIm: Collaborative digital pathology (Fonds Unitaires Interministriels) French Ministry of Industry (MINEFE) : http://www.systematic-paris-region.org/en/projets/flexmim.

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